INDOOR AIR QUALITY ASSESSMENT

K.C. Coombs Elementary School
152 Old Barnstable Road
Mashpee, Massachusetts 02649

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program

September 2005

Background/Introduction

At the request of Brad Tripp, Director of Facilities for Mashpee Public Schools (MPS), and Marina Brock of the Barnstable County Health Department, the Massachusetts Department of Public Health's (MDPH) Center for Environmental Health (CEH) provided assistance and consultation regarding indoor air quality at the K.C. Coombs Elementary School (CES), 152 Old Barnstable Road, Mashpee, MA. The request was prompted by general indoor air quality concerns and complaints of poor ventilation from building occupants.

On June 15, 2005, the school was visited by Cory Holmes, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program, to conduct an indoor air quality assessment. Mr. Tripp accompanied Mr. Holmes during the assessment.

The CES is a two-story concrete block and steel building with vinyl siding that was constructed in 1988. Upgrades to the ventilation system were reportedly conducted in the mid 1990s. The school contains general classrooms, a gymnasium, media center, administrative offices, kitchen and cafeteria.

Methods

Air tests for carbon dioxide, carbon monoxide, temperature and relative humidity with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using an Hnu, Snap-on Model 580 Series Photo Ionization Detector (PID).

Results

The school houses students in grades pre-K through 2 with a student population of 477 and a staff of approximately 80. Tests were taken during normal operations at the school. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were above 800 parts per million parts of air (ppm) in two of eleven areas surveyed indicating inadequate air exchange in these areas. However, some areas were empty or sparsely populated due to end-of-year activities, and windows and exterior doors were open in several areas at the time of assessment. Low occupancy and open windows/exterior doors can greatly reduce carbon dioxide levels. Carbon dioxide levels would be expected to be higher with increased occupancy and with windows/exterior doors shut.

Mechanical ventilation in classrooms was originally provided by two wall-mounted vents located at the front of each classroom (Picture 1). One of the vents served as a supply vent that was ducted to an air handling unit (AHU) on the roof. The second vent served as a passive exhaust, which operates on the premise of pressurization. As air enters the room through the mechanical supply vent, the room becomes pressurized, which forces air into the exhaust vent creating air exchange. Once air is forced into the exhaust vent, it enters the attic which serves as an open plenum that is naturally vented with louvered gable vents (Picture 3). The mechanical ventilation system was upgraded in the mid 1990s, which added a number of additional AHUs on the roof (Picture 4) that are ducted to ceiling-mounted supply vents (Picture 5) as well as the original wall-mounted supply vent from the existing system. However, the exhaust system remains unchanged.

Mr. Holmes and Mr. Tripp examined conditions in the ceiling plenum and discovered that the passive exhaust vents were being ducted to the attic through loosely constructed ducts made of gypsum wallboard (GW). GW is not a good material for ductwork for a number of reasons. First, ductwork should be continuous and is generally made of sheet metal in the form of a round or rectangular airtight duct. Secondly, ductwork should be made of a non porous material that will not absorb moisture in order to prevent microbial growth. Several breaches were observed in the GW "duct" where it had become damaged (Picture 6). These breaches can allow heated or cooled air to vent into the attic space, creating an imbalance in the ventilation system. This imbalance can lead to temperature/comfort complaints, which were among the complaints expressed by building occupants.

Additionally, the location and design of the exhaust system can limit exhaust efficiency. Exhaust vents are located near hallway doors. When classroom doors are open, the classroom loses pressure reducing the effectiveness of the exhaust vent to remove common environmental pollutants. Without exhaust ventilation, excess heat and environmental pollutants (e.g., carbon dioxide) can build up and lead to indoor air/comfort complaints.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years (SMACNA, 1994). The date of the last balancing was not available at the time of the assessment.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, consult Appendix A.

Temperature measurements on the day of the assessment ranged from 71° F to 76° F, which were within the MDPH recommended comfort range of 70° F to 78° F. Temperature control complaints were expressed by occupants to MDPH staff in a number of areas. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity measured on the day of the assessment in the building ranged from 41 to 51 percent, which also within the MDPH recommended comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

A few areas had water-damaged ceiling tiles, which can indicate leaks from the roof or plumbing system. Water-damaged ceiling tiles can provide a source for mold growth and should be replaced after a water leak is discovered and repaired. Missing/damaged roof shingles were observed in several areas (Picture 7). Mr. Tripp reported that these areas had become damaged during the winter storms of 2004-2005 and that MPS maintenance staff were in the process of making repairs, which was evident by rigging/scaffolding on the building exterior (Picture 8).

Open seams between the sink countertop and wall were observed in several rooms (Picture 9). If not watertight, water can penetrate through the seam, causing water damage. Improper drainage or sink overflow can lead to water penetration of countertop wood, the cabinet interior and behind cabinets. Like other porous materials, if these materials become wet repeatedly they can provide a medium for mold growth.

In several areas around the building, clinging plants were noted on exterior walls (Picture 10). The growth of plants/roots against the exterior walls and along the foundation can bring moisture in contact with wall brick and eventually lead to cracks and/or fissures in the foundation below ground level. Clinging plants can cause water damage to brickwork by inserting tendrils into brick and mortar. Water can penetrate into the brick along the tendrils, which can subsequently freeze and thaw during the winter. This freezing/thawing action can weaken bricks and mortar, resulting in wall damage.

Plants were observed in several classrooms. Plants, soil and drip pans can serve as sources of mold growth. Plants should be properly maintained, over-watering of plants should be avoided and drip pans should be inspected periodically for mold growth. Plants should also be located away from ventilation sources to prevent aerosolization of dirt, pollen or mold.

A gutter/downspout system provides drainage, however several of the downspouts were missing during the assessment (Picture 11), which can allow rainwater to pool on the ground at the base of the building or against exterior walls. The freezing and thawing action of water during winter months can create cracks and fissures in the foundation. Over time, this process can undermine the integrity of the building envelope and provide a means of water entry into the building through capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001).

Other IAQ Evaluations

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, MDPH staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were non-detect or ND (Table 1). Carbon monoxide levels measured in the school were also ND (Table 1).

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particle levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 9 μg/m^3 (Table 1). PM2.5 levels measured indoors ranged from 10 to 22 μg/m^3 (Table 1). All PM2.5 measurements were below the NAAQS of 65 μg/m^3. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were ND (Table 1). Indoor TVOC concentrations were also ND (Table 1).

Please note, that the TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. While no measure able TVOC levels were detected in the indoor environment, VOC-containing materials were noted. A number of classrooms also contained dry erase boards and dry erase markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, (e.g. methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999), which can be irritating to the eyes, nose and throat.

Several areas contain photocopiers and lamination machines. Lamination machines can produce irritating odors during use. VOCs and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, 1992). These areas are equipped with local exhaust ventilation; occupants should ensure that vents are operating to help reduce excess heat and odors.

In an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs (Picture 12). Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and off-gas TVOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix B (NIOSH, 1998). Consideration should be given to replacing tennis balls with alternative glides (Picture 13).

Several other conditions that can affect indoor air quality were noted during the assessment. In some classrooms items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items, (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up. A number of exhaust/return vents and personal fans had accumulated dust (Picture 14). If exhaust vents are not functioning, backdrafting can occur, which can re-aerosolize dust particles. In addition, these materials can accumulate on flat surfaces (e.g., desktops, shelving and carpets) in occupied areas and subsequently be re-aerosolized causing further irritation. Dust can be irritating to eyes, nose and the respiratory tract.

Lastly, AHUs are normally equipped with filters that strain particulates from airflow. The dust spot efficiency is the ability of a filter to remove particulates of a certain diameter from air passing through the filter. Filters that have been determined by ASHRAE to meet its standard for a dust spot efficiency of a minimum of 40 percent would be sufficient to reduce airborne particulates (Thornburg, 2000; MEHRC, 1997; ASHRAE, 1992). The filters installed in AHUs at the CES are high dust spot efficiency pleated air filters (reportedly changed four times a year). However, MDPH staff observed AHUs on the roof and found a number of the filters crushed/damaged (Picture 15). Mr. Tripp explained that this was an ongoing problem with cardboard-framed filters being "sucked-in" by the AHU intake fans. Without filters in place, spaces around filters can allow for unfiltered air to bypass the filters and be distributed by the AHUs. Mr. Tripp suggested a support framework could be made to prevent buckling of cardboard framed filters.

Conclusions/Recommendations

In view of the findings at the time of the MDPH visit, the following recommendations are made:

1. Continue with current filter media and schedule. Contact an HVAC filter manufacture/vendor for advice on preventing filter damage or consider fabricating framework to support filters without impeding airflow. Ensure filters fit flush in their racks with no spaces to prevent bypass of unfiltered air.
2. Consult a ventilation engineer concerning balancing of the ventilation systems. Ventilation industrial standards recommend that mechanical ventilation systems be balanced every five years (SMACNA, 1994). Close classroom doors to maximize exhaust function.
3. Use openable windows in conjunction with classroom univents and exhaust vents to increase air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
4. Based on the efficiency, physical configuration and design of the HVAC system, the MDPH strongly recommends that an HVAC engineering firm fully evaluate the ventilation system for proper operation, and/or repair/replacement considerations.
5. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with

wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

6. Continue to make roof repairs to prevent potential water penetration.
7. Ensure all plants are equipped with drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial where necessary.
8. Remove clinging plants from exterior walls.
9. Seal areas around sinks to prevent water-damage to the interior of cabinets and adjacent wallboard. Inspect adjacent areas for water-damage and mold growth, repair/replace as necessary. Disinfect areas of microbial growth with an appropriate antimicrobial as needed.
10. Replace missing elbows to downspouts in a manner to direct rainwater away from the building.
11. Clean accumulated dust from blades of personal fans.
12. Consider discontinuing the use of tennis balls on furniture and replacing tennis balls with alternative "glides" (Picture 13).
13. In order to maintain a good indoor air quality environment on the building, consideration should be give to adopting the US EPA document, "Tools for Schools", which can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.
14. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

References

ASHRAE. 1992. Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 52.1-1992.

ASHRAE. 1989. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-1989

BOCA. 1993. The BOCA National Mechanical Code/1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL.

MEHRC. 1997. Indoor Air Quality for HVAC Operators & Contractors Workbook. MidAtlantic Environmental Hygiene Resource Center, Philadelphia, PA.

NIOSH. 1998. Latex Allergy A Prevention. National Institute for Occupational Safety and Health, Atlanta, GA.

NIOSH. 1997. NIOSH Alert Preventing Allergic Reactions to Natural Rubber latex in the Workplace. National Institute for Occupational Safety and Health, Atlanta, GA.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R 1910.1000 Table Z-1-A.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0.

Schmidt Etkin, D. 1992. Office Furnishings/Equipment & IAQ Health Impacts, Prevention & Mitigation. Cutter Information Corporation, Indoor Air Quality Update, Arlington, MA.

SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

SBAA. 2001. Latex In the Home And Community Updated Spring 2001. Spina Bifida Association of America, Washington, DC. Http://www.sbaa.org/html/sbaa_mlatex.html

Thornburg, D. 2000. Filter Selection: a Standard Solution. *Engineering Systems* 17:6 pp. 74-80.

US EPA. 2000a. National Ambient Air Quality Standards (NAAQS). . US Environmental Protection Agency, Office of Air Quality Planning and Standards, Washington, DC. http://www.epa.gov/air/criteria.html.

US EPA. 2000b. Tools for Schools. Office of Air and Radiation, Office of Radiation and Indoor Air, Indoor Environments Division (6609J). EPA 402-K-95-001, Second Edition. http://www.epa.gov/iaq/schools/tools4s2.html

Picture 1

Wall-Supply Vent for Original System

Picture 2

Passive Exhaust Vent

Picture 3

Louvered Gable Vent

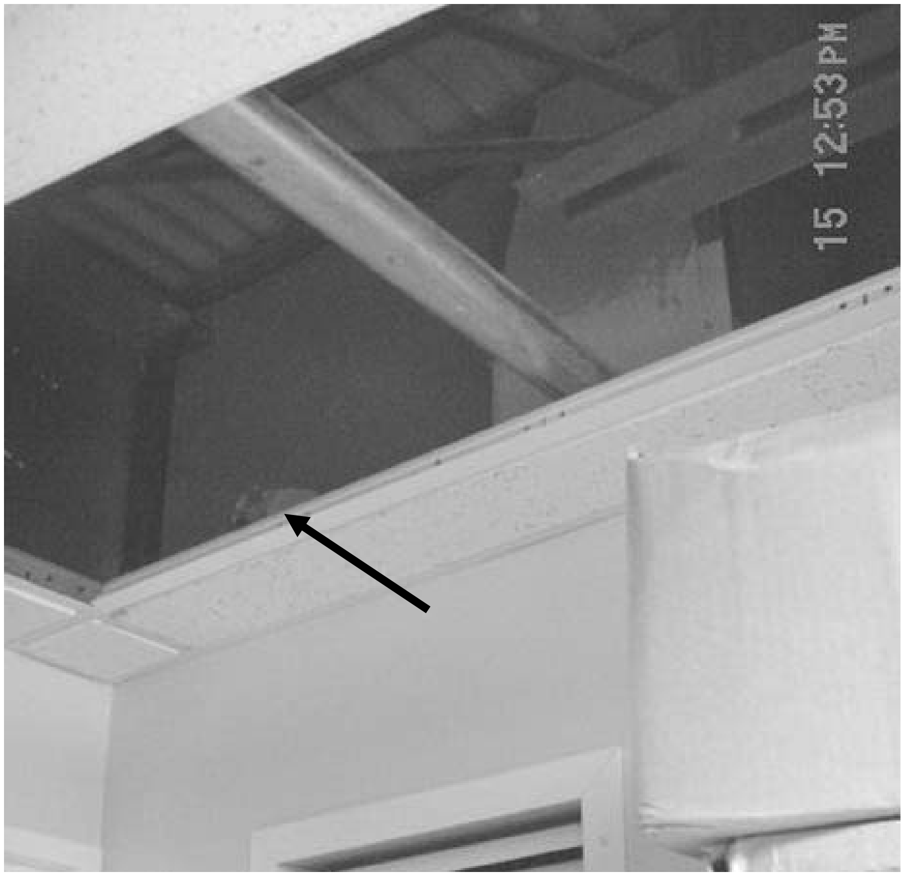
Picture 4

Ducted Rooftop AHU

Picture 5

Ceiling-Mounted Supply Vent

Picture 6



Gypsum Wallboard (GW) Ductwork for Passive Exhaust System above Ceiling Tiles, Note Large Hole in (GW)

Picture 7

Missing/Damaged Shingles

Picture 8

Section of Roof under Repair

Picture 9

Space between Sink Countertop and Backsplash

Picture 10

Clinging Plants in Semi-enclosed Courtyard

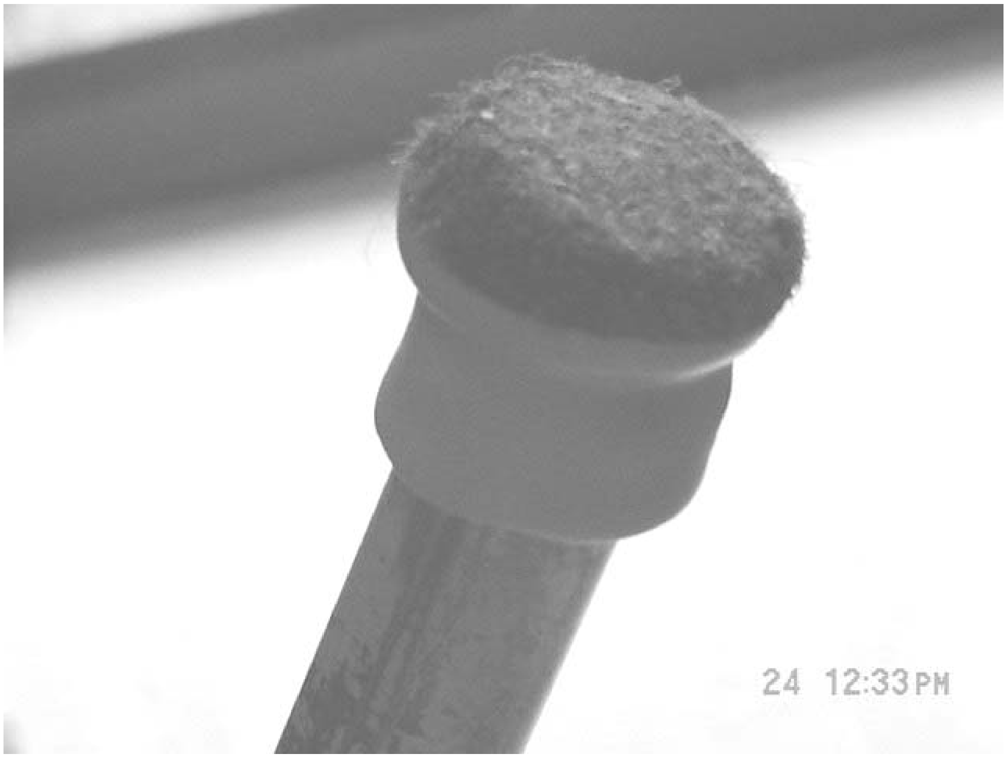
Picture 11

Missing Elbow on Downspout

Picture 12

Tennis Balls on Chair Legs

Picture 13



“Glides” for Chair Legs that can be used as an Alternative to Tennis Balls

Picture 14

Dust Accumulation on Personal Fan in Classroom

Picture 15

Crumpled/Damaged Filters in Rooftop AHU

Kenneth C. Coombs School

152 Old Barnstable Rd, Mashpee, MA 02649

Indoor Air Results

Date: 06/15/2005

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
background		56	52	396	ND	ND	9				NW winds 10-15 mph, gusts 20-25, mostly cloudy.
cafeteria	150	72	51	627	ND	ND	18	Y # open: 0 # total: 8	Y ceiling	Y wall	Hallway DO,
171	16	72	46	648	ND	ND	10	Y # open: 3 # total: 4	Y ceiling wall	Y wall	breach sink/counter, CD, PF.
131	6	73	45	511	ND	ND	12	Y # open: 0 # total: 9	Y ceiling	Y wall	Hallway DO, #WD-CT: 3, breach sink/counter.
229	20	74	44	732	ND	ND	12	Y # open: 1 # total: 3	Y ceiling	Y wall	Hallway DO, #WD-CT: 2, PF.
230	21	76	46	1190	ND	ND	21	Y # open: 0 # total: 3	Y ceiling	Y wall	DEM.

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Kenneth C. Coombs School | **Indoor Air Results**

152 Old Barnstable Rd, Mashpee, MA 02649 | **Date: 06/15/2005**

Table 1

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
168	19	72	46	773	ND	ND	19	Y # open: 1 # total: 3	Y ceiling (weak)	Y wall	Hallway DO, PF, items.
167	14	74	49	1108	ND	ND	22	Y # open: 0 # total: 4	Y ceiling (weak)	Y wall	Hallway DO, items.
236	1	75	41	450	ND	ND	11	Y # open: 1 # total: 4	Y ceiling	Y wall	
135	9	74	46	691	ND	ND	12	Y # open: 0 # total: 5	Y ceiling	Y wall	#WD-CT: 1, PF.
234	12	73	41	658	ND	ND	13	Y # open: 2 # total: 5	Y ceiling	Y wall	DEM, PF.
235	21	71	41	586	ND	ND	12	Y # open: 3 # total: 4	Y ceiling	Y wall	Hallway DO, PF.

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium
AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials
design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile
NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings
sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%